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(19)

(54) MICROWAVE OVEN

(71) We, HUSQVARNA VAPENFABRIKS AKTIEBOLAG, 561 01 Huskvarna, Sweden, a Swedish Company, do hereby declare the invention for which we pray that a Patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention relates to microwave ovens.

Microwave ovens of known types are provided with an oven chamber which, when microwave energy is fed into it, gives rise to a number of resonances, as a result of which the impedance constituted by the chamber in respect of the waveguide and the microwave generator becomes relatively insensitive to the shape and dimensions of the object to be treated. Ordinarily this means that energy transmission from the generator to the objects takes place in accordance with the so-called cavity resonance principle, i.e. a pattern of standing waves is formed in the cavity. However, whatever the condition, there is a certain lack of adaption between the cavity and the waveguide/generator so that energy is returned which must be discharged into the environment as lost heat for example by means of a cooling arrangement.

It is an object of the present invention to provide an improved microwave oven.

For the purpose of this Specification the term 'near field' is explained below.

Starting with Maxwell's equation, the electrical field intensity of a dipole may be reduced to the following expressions:

$$1)\quad E_r = 2A\, Z_o \cos\theta \left[\frac{1}{2\pi}\left(\frac{\lambda}{r}\right)^2 - \frac{j}{(2\pi)^2}\left(\frac{\lambda}{r}\right)^3 \right]$$

$$2)\quad E_\theta = A\, Z_o \sin\theta \left[j\left(\frac{\lambda}{r}\right) + \frac{1}{2\pi}\left(\frac{\lambda}{r}\right)^2 - \frac{j}{(2\pi)^2}\left(\frac{\lambda}{r}\right)^3 \right]$$

λ=wavelength of the microwave radiation in free space

r=distance from source of radiation

A, Z_o=constants

This indicates that the electrical field intensities E_r and E_θ (see Figure 1) diminish in three different ways, i.e. by the sectors λ/r and $(\lambda/r)^2$ as well as $(\lambda/r)^3$. In this connection, r is the distance from the dipole, which may be assumed to be a short dipole, and λ is the wavelength. For small values of r terms of higher order naturally predominate, but in the case of high value of r, we need only consider the λ/r term. A near field, the point of origin of which is the radiating dipole, is defined at that range of the electromagnetic field which is situated within a distance of $r=\lambda$ from a radiating element. It is therefore a premise for the existence of a near field that the distance from the radiating element is at the most of the order of magnitude of a wavelength.

In the near field, energy is transmitted by a "transformer action", i.e. the field induces displacement currents in the load and these displacement currents produce, in the usual manner, heat owing to dipole resonance or conductivity phenomena in the load. In the far field and in microwave ovens which constitute resonators, energy coupling occurs, capacitively, whereas in the near-field inductive energy overcoupling is also brought about. Another important point in this connection consists in the fact that the charac-

teristic wave impedance which in the case of a plane wave amounts to 377 ohms in a vacuum, varies in the near field within wide limits. Hence, coupling which varies rapidly in relation to the wavelength is brought about in the near field and consequently transmission of power even to those parts of the load which differ widely as regards their dielectric properties. Inasmuch as the transmission of power varies in intensity between very closely adjacent points, we obtain, on the one hand, very good adaptation between the generator and the load, and on the other hand very rapid temperature equalisation through the heat line, which is only required over a very short distance.

In the case of heating food-products which have greatly differing dielectric properties, and hence normally differing adaption characteristics in respect of the microwaves (example: food during defrosting), heating by means of near field applicators gives considerably better results than can be achieved with conventional cavity resonance ovens. The tendencies to resonance formation (i.e. standing waves) in the food-product are reduced considerably by the firm coupling between the radiating element and the load. Burning of edges, a phenomenon closely akin to resonance formation, is not nearly so pronounced if a near field applicator is used.

In order to achieve the above mentioned targets as regards the heating result, at least two conditions must accordingly be satisfied. The first one consists in that the load shall be located within the near field, i.e. substantially within the distance of one wavelength from a radiating element. In the second place, the energy transmission between generator and load shall take place to the least possible extent in accordance with the cavity resonance principle. This does not mean that reflections are to be eliminated entirely. If an enclosed oven chamber is required, in order to achieve a high degree of efficiency and for reasons of safety, it is advisable to provide at least one "top" in the oven chamber. If the height of the "top" is optimally selected we can achieve a certain co-operation between the direct and the reflected fields. This will only be successfully achieved if there is no resonant space. The height of the top shall therefore amount to less than one wavelength.

According to Babinet's principle it is possible, from the point of view of field formation, to use instead of a dipole a guide in the chamber with a corresponding slot in a conducting plane. Hence, one makes use, in practice, of slots in the broad sides of the waveguides, the dimensions of the slots being so chosen that they are substantially in resonance.

According to the present invention there is provided a microwave, a microwave oven comprising an oven chamber, a carrier for an object to be heated, a chamber boundary surface located above the carrier by a distance not more than the wavelength of the applied microwave radiation, the boundary surface being defined by a removable reflector slidably received in the oven chamber, and which is capable of reflecting the applied microwave radiation, and at least one wave guide located below the carrier for supplying microwave radiation to the oven chamber.

Embodiments of a microwave oven according to the present invention are particularly described below by way of example only, with reference to the attached drawing in which:

Figure 1 shows a dipole aerial with surrounding fields E_r and E_0;

Figure 2 shows a microwave oven, the base of which is formed by the flat side of a waveguide fed with microwave power, and

Figure 3 shows a microwave oven in which two waveguides arranged at right angles to one another lead into the base of the oven.

Referring to the drawings the height of the top 8 from the oven bottom 2 is about one wavelength of the applied radiation i.e. at the frequency of 2,400 MHz it is about 12cm The sides 1, 3, bottom 2 and the cover 4 of the oven chamber are mainly intended to retain the microwave radiation within a limited space. The radiation enters the oven chamber in accordance with Figure 2 through slots 5 in one side wall of a wavelength 6 with mode transformation. Such a waveguide is described in greater detail in our co-pending Patent Application No. 48481/71, Publication No. 1364734 and is provided in this case with a power outlet in one broad side of the waveguide, which is thus closed at its outer end. The waveguide projects on one side beyond the oven chamber and is there provided with a connection for a magnetron.

Each slot of the waveguide serves as a radiating element and is surrounded by a field pattern similar to the one shown around the dipole in Figure 1. An object to be heated, is placed on the oven bottom which serves as a carrier for the object and, is subjected to the near field by the radiating slots of the oven, which are distributed in a pattern over the entire base area of the oven. In order to achieve optimal efficiency, the object should be shaped in such a way as to cover the entire pattern of slots. The efficiency also depends on the energy absorption characteristics of the object, there being highly absorbent objects such as coal and ferrite alloys, whereas other materials encountered e.g. in foodstuffs have absorption characteristics which are poorer. That part of the microwave power, which penetrates through the object, is reflected from the top 8 of the oven and enter the object

again. The total efficiency with which the energy is transmitted to the object is, as a result, particularly high.

In order to vary the height of the oven a reflector in the form of a metal plate 9 is provided which can be slidably introduced into grooves (not shown) in the opposite sidewalls 1, 2 of the oven chamber, the plate 9 being capable of reflecting the applied radiation. The plate is pushed in parallel with the oven bottom and forms a "top" replacing the one formed by the original cavity. In this way the resonances are eliminated since the new oven chamber is much lower than the previous one. The new chamber has a height which is suitable e.g. for heating deep-frozen foodstuffs.

Another embodiment of the invention is shown in Figure 3. This oven is provided with two vertical waveguides 10, 11 at right angles in respect of one another and with mode transformation. They lead direct into the oven chamber (there are no direct slots but the field pattern achieved is substantially the same as that brought about by a full wave dipole). The oven is parallelepiped in shape and can be regarded as constituting a section of a panel oven, if the cover is removed and the rear of the oven is kept open. In the given design a rotatable disc 12 is provided at the base level as a carrier for the object to be heated. The disc is located by means of a spindle 13 and kept in rotation with the aid of a motor 14. Hence, some part of the object is always within a heating zone near a waveguide opening so that the radiation "sweeps" over the entire object while it is being rotated. The oven output can be further increased by introducing a greater number of waveguides than the two shown.

The two embodiments of a near field oven in accordance with the invention as illustrated and herein described shall be regarded as example of how the near field from a source of radiation can be practically utilised within an area in which formerly a different principle of transmitting microwave power to an object has been entirely predominant. Only two different types of radiation openings have been described above but there are of course other types of radiating elements equivalent to those described. Hence, what specially characterises the invention is not the design of the radiating element but the arrangement of an oven chamber the dimensions of which are so chosen that no standing waves occur, waves emanating from the radiation element being, however, reflected from one of the boundary surfaces of the oven chamber.

WHAT WE CLAIM IS:—

1. A microwave oven comprising an oven chamber, a carrier for an object to be heated, a chamber boundary surface located above the carrier by a distance not more than the wavelength of the applied microwave radiation, the boundary surface being defined by a removable reflector slidably received in the oven chamber and which is capable of reflecting the applied microwave radiation, and at least one wave guide located below the carrier for supplying microwave radiation to the oven chamber.

2. A microwave oven according to claim 1 wherein the oven chamber constitutes a cavity resonance applicator if the reflector is removed.

3. A microwive oven according to claim 1 or 2 wherein the oven chamber constitutes a near-field applicator if the reflector is mounted.

4. A microwave oven according to any preceding claim wherein one waveguide is provided which is of substantially rectangular cross-section, a broad side of the wave guide forming the bottom of the oven and having radiation openings formed therein.

5. A microwave oven according to claim 4 wherein the radiation openings are slots each having a length corresponding to approximately half of wave-length of the applied radiation.

6. A microwave oven according to any of claims 1 to 3 wherein two waveguides are provided, each being arranged so that their end opening opens out into the oven chamber, and the carrier is formed by a disc rotatably located above the openings.

7. A microwave oven according to any preceding claim wherein the oven is parallelepiped in shape and two mutually opposite sides of the oven are open for connection to sections of a panel oven.

8. A microwave oven substantially as described with reference to and as illustrated in Figure 1 or in Figure 2 of the accompanying drawings.

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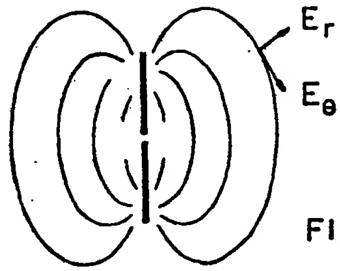

FIG. 1

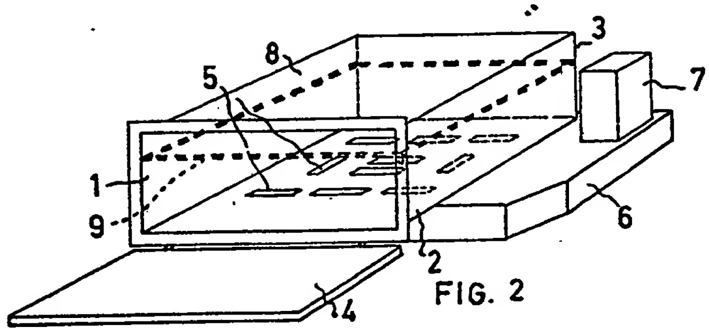

FIG. 2

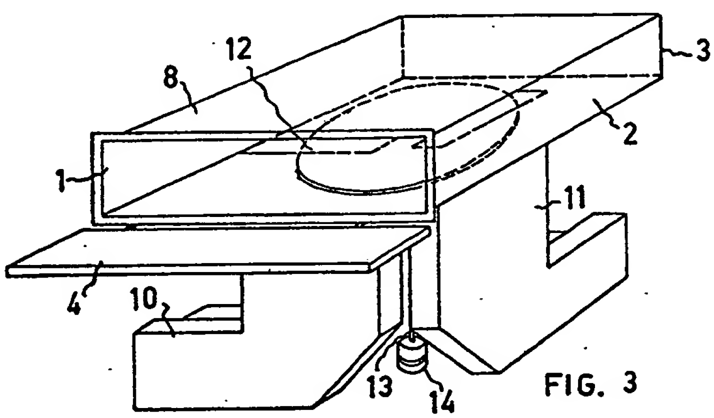

FIG. 3